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Design and Construction of Remote Control for Lighting System Using Infra Red

***T.O. Daniel*[1] *and D. Ochola*[2]**

[1]Department of Physics, Sule Lamido University, P.M.B 048, Kafin Hausa.
[2]Department of Electrical & Computer Engineering, Ahmadu Bello University Zaria.

Abstract

The study investigates the design, construction and testing of a lighting system using infra-red remote control. A single channel remote control is used to control the switching of alighting system connected to the output of an Infra-red receiver. An Infra-red beam is modulated by an oscillator (NE 555 timer IC) and transmitted to a remote sensor (TSOP1738). This signal is amplified by a transistor (BC 558) and then delivered to the decade counter (CD 4017 IC) via its clock input terminal. The transistor output is fed to an electro-mechanical relay which does the switching of the load. The system is found to be effective and operational within the range of 0.01 m to 10 .05 m in accordance with the design specifications.

Keywords: Infra-red, remote control, Transistor, Integrated circuit.

1.0 Introduction

An infra-red remote control is an electronic device used for the distance operation of a lighting system or a machine [1]. It is known by many other names such as the “clicker”, “channel-changer” or “selector”. Most remote control system for electronics appliances uses an infra-red diode with a single channel (single- function, one button) remote control in which the presence of a carrier signal can be used to trigger a function. For multi-channel (normal multi-function) infra-red remote control, more sophisticated procedures are necessary. One consists of modulating the carrier signals with signals of different frequencies. After the demodulation of the received signal, the appropriate frequency filters are applied to separate the respective signals, but nowadays, digital procedures are commonly employed. Some remote controls use radio frequency signals which emit a beam of light that reaches the device. A 940 nm wave-length LED is a typical example [2]. This infra-red light is invisible to the human eye but carries signals that are detected by the appliance, as well as by the sensor of a digital device. Infra-red remote control is mostly used to issue command from a distance to lighting system or other consumer electronics appliances such as televisions, stereo system and DVD players. These infra-red remote controls are usually small wireless hand held objects with an array of buttons for adjusting various settings of the appliances such as television channels, track number, and volume. Following the technological advancement of this modern age, the use of miniaturized electronic circuits to control both electrical/electronic systems is really becoming popular. It could be very interesting too to see how points of light in our homes are being controlled by a single remote instead of switches. This implies that one can sit or lie down somewhere in his room and yet control lighting points elsewhere in the room and even outside. To have a simple and easy to operate remote system to control electrical/electronic facilities and appliances is a great advantage, particularly for the aged and sick persons. Hence this study aims at finding an easy way of turning the electrical/electronic device “ON/OFF” without necessarily moving to the device by using infra-red.

2.0 Review of Relevant Literature

Ojo [3] investigated the Design and Construction of an Ultrasonic Remote Control System” to simply put “ON/OFF” electronics appliances but had limitation of difficulty to differentiate between the sound from the ultrasonic remote and other sounds. Therefore, the system was prone to greater interference. Popoola [4] studied the Design, Construction and Testing of an Infra-red Remote Control System to put “ON/OFF” lighting system with the receiver circuit comprising of many logic gates and Op-Amps making the work very complex and tedious. Ibrahim [2] designed and constructed a remote control fan regulator which was able to control a fan but only at a maximum distance of five meters from the device. The design suffers signal attenuation and noise generation because of the modulation and demodulation stages involved, hence the need to

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Corresponding author: T.O. Daniel, E-mail: danielojonugwathomas@gmail.com, Tel.: +2348065732254

incorporate a tuned circuit to eliminate noise interference in the system. Innocent [5], designed and constructed an infra-red remote control for lighting system to "ON/OFF" the lighting system. The limitation of his work was that the receiver circuit comprises of many logic gate components which makes the circuit complex. Also, it could only control a device at a maximum distance of 5 meters. From literatures reviewed, how to modify the circuits to improve system performance was the common goal of all. All things being equal, those who carry out the design and construction of this project work knew the importance of using remote to control a lighting system without necessarily going to put "OFF/ON" on each switch controlling the lighting points. Meanwhile, individuals who design this project have different perspective of what distance they actually want to cover. This depends greatly on the individual mindset and the kind of device he/she wishes to control in order to achieve its purpose.

However, in view of these limitations, this research intends to incorporate an additional amplifier unit and sensor unit to the transmitter circuit in order to control a lighting system from an approximate distance of 10 meters. Also, the complex receiver circuit was replaced with a simple circuit using ICs instead of logic gates. Packaging or casing is another important aspect of this project which has suffered negligence from time past. It is an important aspect which makes it look very attractive and durable. These are the areas of interest this work is set to address.

3.0 Experimental Work

The experimental frame work of the study involves the design of power supply unit, design of the infra-red transmitter unit (Transmitter), design of the infra-red detector unit (Receiver), design of the signal amplifier unit, design of the electromechanical relay unit (interface), integration of the various units into a system, construction and testing of the workability of the system. The device uses components which can operate safely within an average voltage of +5 to 9V.Since the component types and ratings are the major factors for the design of the power supply unit, the transformer used is such that it matches the source impedance to the load impedance and consequently achieving a maximum power transfer from the source to the load. This is done in order to minimize unnecessary power wastage. In order to calculate the maximum current that the transformer can supply effectively without overheating, the maximum current required by the entire system is shown in Table 1.

Table 1: Current and voltage values of major components that constitute the system [6]

Components	**Max. current**	**Quantity**	**Total Current**	**Max. DC voltage**
NE 555 Timer IC	435 nA	1	435 Na	8.53 V
Transistor	810.11 µA	1	810.11 µA	868.35 mV
Diode	159.49mA	4	537.96mA	8.99V

From Table 1, the maximum current for the entire circuit is found to be 320mA since only two diodes out of four conducts at a time in a full wave bridge rectification. Hence, a transformer of 500mA is recommended to avoid overheating since heat dissipation is proportional to current taken by the load and a 220-240V, step down transformer with primary voltage of 240V and a secondary voltage of 12V is used. This transformer is assumed to work in an ideal situation (that is, unity power factor).

Therefore the load and the source impedance are expressed [7] as:

$Turn\ ratio = 1/K \quad =(1/20)$

$K = Np/Ns$ (1)

$1/K = \sqrt{(Zload/Zsource)}$

Where, Ns = secondary windings, Np = primary windings, Zload= load impedance (Ohms) and Zsource= internal impedance of the source (Ohms)

$Zsource = Vdc/Idc$ (2)

Where $Vdc = 12V\ and\ Idc = 500mA$

$$Zsource = \frac{12V}{500mA} = 24\ Ohms$$

$Zload = (turn\ ratio)^2 \times\ Zsource = 0.06\ \Omega$

$Turns\ ratio\ Ns/Np = \sqrt{(0.06/24)} = 0.05$

To obtain the dc current

$Idc = 2 \times Irms \times \sqrt{2}/\pi$

But $Irms = 500$mA

$Idc = 450mA$ (Calculated maximum secondary current due to losses).

Therefore, the voltage across the bridge diode Vdc is [8]:

$Vdc = \sqrt{2} \times Vrms$ (3)

$Vdc = 12 \times \sqrt{2} = 17\ V$

The diode (D1-D4) adopted in this study is IN4007 due to its low peak inverse voltage (PIV) which is approximately 50V. A bridge rectifier is used because it helps in lowering the peak inverse voltage. The diode forward voltage (Vf) across the rectifier diode is multiplied by two (2) due to the positive and negative half cycle flow of the signal pulse,

$$PIV = 2 \times Vf = 2 \times 17 = 34\,V \tag{4}$$

PIV of 34V is used for the design which is less than the 50V rated PIV.The PIV is the maximum reverse voltage a diode can withstand before it breaks down. Since the output voltage of the transformer is 12V, the bridge rectifier diodes have a PIV greater than Vdc, so the damage to the diodes is prevented.Capacitor C1 is selected as follows to filter ripples from voltage supply to the circuit.

The ripple factor is given by [9]:

$$Y = 1/4\sqrt{(3RlFC)} \tag{5}$$

Where

Rl $(load\ resistance)$= 24 Ohms (thesame as Zsource earlier calculated),

f (frequency) = 50Hz (standard electricity supply frequency)

Y = 5 percent minimum standard ripple factor [10]

Equation (5) becomes,

$$0.05 = 1/4\sqrt{3} \times 24 \times 50 \times C1$$

C1 = 24100μF. But a value of 2200μF is selected which is available in the market.

The capacitor voltage (Vcap) is given as [11].

$$\text{Vcap} = 2\text{Vcmax} - \text{Vbr} \tag{6}$$

$$\text{Vcmax} = Vrms\sqrt{2}$$

Vcap= $Vrms\sqrt{2} \times 2 - Vbr$; Vbr = 1.4 (standard maximum diode voltage drop).

$$Vcap = 2\sqrt{2} \times 9 - 1.4$$

Vcap = 24.05, (25V is recommended for market availability).

Hence, an electrolytic capacitor of capacitance 2200μF, 25V was selected for better filtration bearing in mind that, the higher the value of the capacitor the lower the ripples.

In order to get high quality precision, a regulator IC LM7812 is selected since the required output voltage needed is 12V. It has some inbuilt unique features such as current limiting, self-protection in case of increase temperature and remote control operation over a wide range of input voltages / fold back current limiting. However, this power supply system is simply suggested for domestic installation and is illustrated in Figure 1.

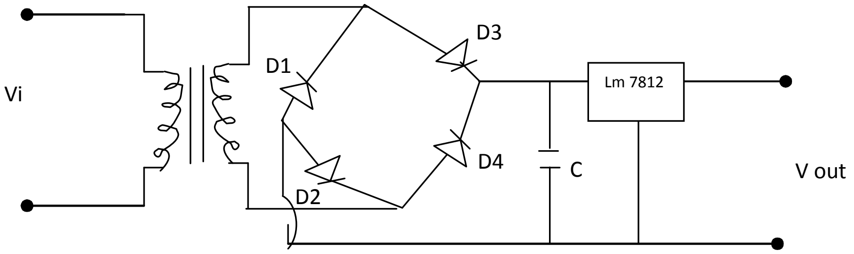


Figure 1: Power supply unit for the device

The circuit diagram of the transmitter circuit is shown in Figure 2 while the circuit diagram of the receiver is shown in Figure 3.

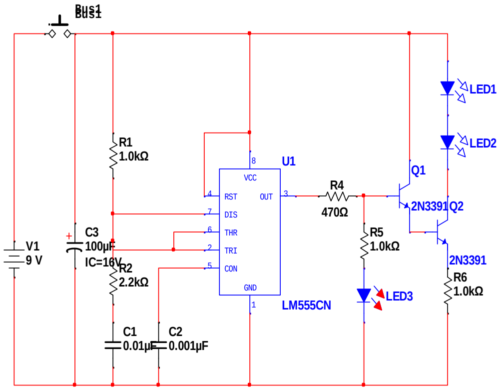


Figure 2: Circuit diagram of a transmitter

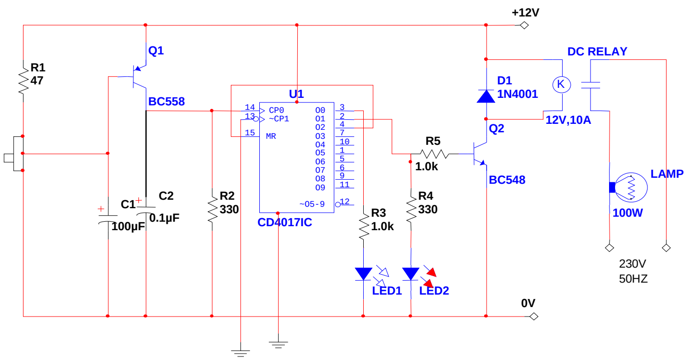


Figure 3: Circuit diagram of the receiver

When the switch is pressed on in the Transmitter, the astable integrated circuit (U1) sends out signals which triggeres the LED to radiate infra-red light at a frequency, f. The capacitor C1charges through resistors R1and R2but dicharges through R2 only. When the capacitor C1 is charging at an interval $0 \le t \le T$, the capacitor voltage is given as [4]:

$V(t) = 1/3V + 2/3V\,(1 - exp(-t/\tau 1))$ (7)

Where τ is the time constant and is given as [12],

$\tau = (R1 + R2)\,C1$ (8)

At time t = T1, capacitor voltage reaches the threshold level such that,

$V(t) = 1/3V + 2/3V\,(1 - exp(-T1/\tau 1))$ (9)

$V(t) = 2/3V$ (Threshold activated at this input level) (10)

Equating (9) and (10) for the timing capacitor charging time, T1 yields

$2/3V = 1/3V + 2/3V - 2/3Ve^{-T1/\tau 1}$ (11)

$V/3 - 2/3Ve^{-T1/\tau 1} = 0$

$V = (1/3 - 2/3e^{-T1/\tau 1})$

$V = 0$

$1 - 2e^{-T1/\tau 1} = 0$

$1 = 2e^{-T1/\tau 1}$

$1/2 = e^{-T1/\tau 1}$(12)

$T_1 = \tau_1 \ln 2$ (13)

But from equation (8)

$t1 = (R1 + R2)\,C1$

Therefore substituting equation (8) into equation (12) we have

$T_1 = \ln 2\,(R1 + R2)\,C1$

$T_1 = 0.693\,(R1 + R2)\,C1$ (14)

When the timing capacitor is discharging during, the time $0 < t < T_2$,

The capacitor voltage is

$V(t) = 2/3 = V\,e^{-T2/\tau 2}$(15)

Where $T2 = R2C1$ (16)

At t2= R2, the capacitor voltage reaches the trigger level and

$V(t) = 1/3\,V = 2/3\,V\,e^{-T2/\tau 2}$

$1 = 2\,e^{-T2/\tau 2}$

$1/2 = e^{-T2/\tau 2}$ (17)

$T2 = \tau 2 \ln 2$ (18)

$T2 = 0.693\tau 2$

But $\tau 2 = R2C1$

$T2 = 0.693\,R2C1$ (19)

The period T of the astable multivibrator cycle is the sum of the charging period T1and discharging period T2.

The frequency of oscillation is therefore f,

$f = 1/T = 1/(T1 + T2)$

$f = 1/(0.693(R1 + R2))\,C1$ [8]

$f = 1.443001/(R1 + 2R2)C1$ (Hz) (20)

Taking R1 = 1kΩ, C1= 0.01µF and f = 38 kHz. Substituting into equation (20) gives

$38k = 1.443/((1K + 2R2) \times 0.01\mu)$

R2= 2.2k Ohms.

The transmitter utilizes a 555 timer IC (LM 555) in astable configuration to give the desired result. It is used as a pulse generator and consists of two voltage comparator, a bi-stable flip-flop, a discharged transistor, and a resistor divider network [6].The Infra-red detector used is a transducer of radiant energy that converts radiant energy in the infra- red into a measured form. This study uses IR detector of 75nW to minimize power dissipation and improve the efficiency of the circuit operation [6, 11].

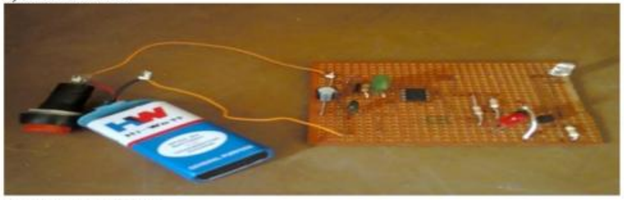
4.0 Construction and Testing

The circuit is first constructed on a temporal bread board to ascertain its ability to work according to the design goals. The components are inserted into the slots on the board and connected accordingly using wires as jumpers. After ensuring that the wiring is done properly and components connected with right orientation, the system is powered using a dc source. The circuit is found functioning as expected. Figure 4 shows the correct layout of the complete circuit of the transmitter on a bread board while Figure 5 shows it layout on a Vero board.

Figure 4: Temporal construction on bread board.

The tested circuit diagram on a bread board is then transferred and soldered on a vero board. The IC socket is put on the vero board and then soldered. The chip is then slotted into the socket to avoid damage due to excessive heat with other necessary precautions taken. Figure 5 shows the vero board connections.

a). Receiver



b). Transmitter

Figure 5: Permanent construction on vero board.

The complete circuit casing of the receiver is shown in Figure 6, while the complete circuit casing of both the receiver and the transmitter (Infra-red Remote control) is shown in Figure 7 taking in to account the weight, ease of installation, thermal conductivity, shock resistance and protection against damage

Figure 6: Circuit casing of the receiver

Figure 7: Circuit casing of transmitter and receiver.

The test employed during the project work is divided into two namely: static and dynamic tests. For the static test, visual inspection is done to ensure that all connections and components are properly made. This is in the form of checking all closed tracks, jumper wires, for open or short circuit; also a resistance test is performed with an ohmmeter. All tests give satisfactory results. While for the dynamic test a Power is fed to the circuit for a short time and then cut off using the finger as a heat sensor, the temperature of the components are felt to see if any is over-heating. When this is satisfied, the switch is then completely turned out. Voltage test is then followed. This is performed with a digital voltmeter. Voltage level at different points on the board is taken and compared with the design specification of 12V. A close march of 11.96V is found with a difference of 0.04V.

4.0 Results

From the test carried out on the final package of the device, the following results were obtained:

1. At a distance of 5 meters from the receiver circuit kept on a strategic corner of the room and ensuring all loads connected, the transmitter is able to activate/deactivate the receiver.
2. Also, at a range of 7 meters, the transmitter turned “ON/OFF” the load (lighting point).
3. Also at a distance of 10 meters between the receiver circuit and the transmitter, there is a perfect signal transfer and switching of the load.
4. Slightly above 10 meters (i.e. 10.05 meters) effective switching control is also observed. But beyond this range, no infra-red signal is actually detected by the receiver.

Finally, the device can effectively detect IR signals within the range of 0.01m to 10.05m. Although, this maximum range is reasonable enough to avoid any form of interference because IR signals do not penetrates through solids.

5. 0 Conclusion

The design, construction and testing of the lighting system using infra-red remote control was successfully carried out. The incorporation of an additional Amplifier unit, a sensor unit to the infra-red transmitter, a tuned circuit and the use of simple IC circuit instead of logic gates previously used helps to reduce the complexity of the circuit and enhances its performance in terms of sensitivity, increase in range of signal reception, reduction of cost, reduction of noise and efficiency in performance. The system is found to be effective and operational in accordance with the design specifications within the range of 0.01m to 10.05m.

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